MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/17

ENT3036 – SEMICONDUCTOR DEVICES
(All sections / Groups)

27 FEBRUARY 2017
9:00 P.M- 11:00 A.M.
(2 Hours)

INSTRUCTION TO STUDENTS

1. This Question paper consists of 6 pages with 4 Questions only.

2. Answer all the questions and all the questions carry equal marks of 25. The distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) (i)Sketch the energy-band diagram of a pn junction under reverse bias, and obtain the total potential barrier. [2+2 marks]

(ii)The space-charge width of n-region in a reverse-bias pn junction is given as

$$x_n = \left[\frac{2\varepsilon_S(V_{bi}+V_R)}{e}\left(\frac{N_a}{N_d}\right)\left(\frac{1}{N_a+N_d}\right)\right]^{1/2}$$

where V_{bi} and V_R are the built-in potential and reverse bias voltage, N_a and N_d are doping concentrations of p- and n- regions, ϵ_s ($11.7\times8.85\times10^{-14}$F/cm) is the permitivity of semiconductor, and e (1.6×10^{-19} C) is the electronic charge.

Derive the junction capacitance and obtain the junction width. Given $V_R = 5$V and $V_{bi} = 0.635$V, calculate the junction capacitance at $T = 300$ K, $N_a = 10^{16}$ cm^{-3}, $N_d = 10^{15}$ cm^{-3}. [6 marks]

(iii)Briefly explain why the pn-junction breakdown field is always higher for GaAs than silicon, irrespective of the doping concentration. [2 marks]

(b) The emitter current (I_E) for an npn bipolar junction transistor (BJT) is measured and is found to be 1.2 mA, the collector is given by

$$I_C = \frac{eD_nA_{BE}}{x_B}\times n_{B0}\exp\left(\frac{V_{BE}}{V_t}\right) \quad \text{and} \quad I_S = \frac{eD_nA_{BE}}{x_B}\times n_{B0}$$

Calculate the base-emitter voltage, $V_{BE} = V_t \ln\left(\frac{I_C}{I_S}\right)$ with the following parameters.

Common-emitter current gain, β	150
Cross-sectional area of the base emitter junction, A_{BE}	1.4×10^{-3} cm^2
Neutral base width, x_B	0.70 μm
Thermal-equilibrium electron concentration in the base, n_{B0}	2.3×10^3 cm^{-3}
Minority carrier electron diffusion coefficients in base, D_n	19 cm^{2}s^{-1}

[7 marks]

(c) With aid of diagrams, briefly describe the following:
(i) Effect of the base-width modulation, and (3 marks)
(ii) Difference between cutoff and beta cutoff frequency in a BJT. (3 marks)

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Question 2

(a) (i) By means of simple diagrams for gate-to-channel space charge regions and corresponding I-V characteristic, explain the pinchoff effect. [2+2 marks]

(ii) Name and briefly explain TWO (2) nonideal effects that could occur in JFET. [2x1 marks]

(b) For a p^+n junction of a uniformly doped silicon n-channel JFET with $N_a = 10^{18}$ cm^{-3}, $N_d = 10^{16}$ cm^{-3} and $T = 300$K. The internal pinchoff voltage (V_{po}) is given as

$$V_{po} = \frac{ea^2 N_d}{2\epsilon_s}$$

where a is the metallurgical channel thickness between the p+ gate region and the substrate, e (1.6×10^{-19}C) the electronic charge and ϵ_s ($11.7\times8.85\times10^{-14}$ F/cm) is the permittivity of the semiconductor.

(i) Given that $V_{po} = 4.35V$, calculate a. [3 marks]
(ii) Given that $n_i = 1.5\times10^{10}$ cm^{-3}, calculate the built-in potential. [3 marks]
(iii) What would be the pinchoff voltage? [2 marks]

(c) (i) Sketch a small-signal equivalent circuit of JFET and label the terminals and components in the circuit clearly. [4 marks]
(ii) Name two frequency limitation factors. [2 marks]
(iii) If the capacitance charging time is the limiting factor, derive the flowing cutoff frequency:

$$f_T = \frac{e\mu_n N_d a^2}{2\pi\epsilon_s L^2}$$

where L is the channel length, and maximum possible transconductance is given by

$$g_{ms} = \frac{e\mu_n N_d W a}{L}.$$ [5 marks]

Continued...

Question 3

(a) With aid of simple sketches, briefly describe the two modes for both n-channel and p-channel MOSFET operations. [6 marks]

(b) An ideal MOS capacitor with a p-type semiconductor has impurity concentration of 8.5×10^{16} cm^{-3} and gate oxide capacitance (t_{ox}) of 7.8×10^{-8} F/cm^2. The intrinsic concentration is given by $n_i = 1.5\times10^{10}$ cm^{-3}, relative permittivity of semiconductor $\varepsilon_s = 11.7$, relative permittivity of insulator $\varepsilon_i = 3.9$ and temperature $(T) = 300$ K. The permitivity of air is given by $\varepsilon = 8.85\text{x}10^{-14}$F/cm.

Determine

(i) the thickness of oxide layer, t_{ox} [2 marks]

(ii) the minimum capacitance achieved, C_{min} [3 marks]

(iii) and the threshold voltage, V_T. [2 marks]

(c) (i) Indicate three regions of operation for Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) in the output current versus the output voltage characteristics. Briefly explain these regions of operation for MOSFET. [3+3 marks]

(ii) An ideal n-channel MOSFET is operated with the following parameters: channel length L =1.5 μm, electron mobility μ_n = 650 cm^2/V-s, and oxide thickness $C_{ox} = 7 \times10^{-8}$ F/cm^2, and threshold voltage $V_T = 0.65$V. What should be the channel width such that I_D (sat) = 5mA for $V_{GS} = 5$V?

[6 marks]

Continued...

Question 4

(a) (i) By using a simplified band diagram of gallium arsenide (GaAs), explain briefly the occurrence of negative differential resistance in Gunn diode. [3 marks]

(ii) Name THREE (3) common applications using Gunn Diode. [3 marks]
What are the advantages and disadvantages of Gunn Diode ? [4 marks]

(b) (i) Draw the voltage–time (*v-t)* graph of the three domain modes for a Gunn oscillator and clearly indicate their differences. [3 marks]

(ii) With aid a diagram, design mm-wave co-axial cavity Gunn oscillator. Show that the oscillator frequency is given by

$$f_n = \frac{cn}{2l}$$

where l is the cavity length, c the speed of light and n is the number of half of the cavity. [8 marks]

(iii) Show also that the above Gunn oscillator can only operate with frequency within :

$$1 \leq n \leq \frac{l}{ct_d}$$

where t_d is the diode response time. [4 marks]

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PHYSICAL CONSTANT:

Thermal voltage:	$V_t = 0.0259$ V
Intrinsic concentration of Silicon at 300K:	$n_i = 1.5\times10^{10}$ cm^{-3}
Intrinsic concentration of Silicon at 373K:	$n_i = 2.5\times10^{12}$ cm^{-3}
Intrinsic concentration of Gallium Arsenide at 300K:	$n_i = 1.8\times10^{6}$ cm^{-3}
Boltzmann's constant:	$k = 1.3806\times10^{-23}$ J/K
Electronic charge:	$e = 1.6\times10^{-19}$ C
Permittivity of free space:	$\varepsilon_0 = 8.85\times10^{-14}$ F/cm
Dielectric constant of Silicon at 300K:	$\varepsilon_r = 11.7$
Dielectric constant of Silicon oxide at 300K:	$\varepsilon_i = 3.9$
Dielectric constant of Gallium Arsenide at 300K:	$\varepsilon_{GaAs} = 13.1$

End of paper.